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KARDIONET: Telecardiology Based on GRID Technology

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Abstract. The telecardiological system Kardionet is being developed to support interventional cardiology. The main aim of the system is to collect specific and systemized patient data from the distant medical centers and to organize it in the best possible way to diagnose quickly and choose the medical treatment. It is the distributed GRID type system operating in shortest achievable time. Computational GRID solutions together with distributed archive data GRID support creation, implementation and operations of software using considerable computational power. Kardionet system devoted to cardiology purposes includes specially developed data bases for the multimodal data and metadata, including information on a patient and his/her medical examination results. As Kardionet uses modern technology and methods we expect it could have a considerable impact on telemedicine development in Poland. The presented telecardiological system can provide a number of important gains for the national health care system if it is implemented nationwide.

Keywords. telemedicine, telecardiology, EPR, GRID

1. Introduction

Telecardiology is the area which could significantly improve the access to medical services and their quality. Especially, it could influence successful treatment of cardiovascular system diseases (CVDs) that are one of the prevailing causes of mortality in many European countries (e.g., in Poland CVDs cause almost 50 percent of all deaths) and is an important contemporary civilization problem. CVDs have also been highlighted as playing an important role in the rise of adult mortality in the countries of Central and Eastern Europe at the beginning of 1990s [1]. Hence, solutions that enable quicker and more efficient medical interventions could save both many years of life and improve life expectancy in the population. In this paper we describe the Kardionet project within which the telecardiological system to support interventional cardiology has been developed. The main aim of the system is to collect specific and systemized patient data from the distant medical centers, and to organize

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them in a best possible way to diagnose quickly and then choose the appropriate medical treatment. The system has been built in cooperation between Interdisciplinary Center of Mathematical and Computational Modeling at the University of Warsaw and Cardiology Clinic and Department of Medical Informatics and Telemedicine at the Medical University of Warsaw. It is the distributed GRID type system that is operating in real time. Computational GRID solutions together with distributed archive data GRID support creation, implementation and operations of software using considerable computational power. With a new generation of solutions used in GRID systems it is possible to monitor computing tasks and resources as well as to efficiently manage processed data and computational power.

2. Kardionet – The Telecardiological System

IT structure of this telecardiological system uses GRID solutions and it is based on the idea of connecting data sources in the metasystem. It incorporates different architectures, platforms and localizations with specific local access and security rules within the special virtual organization (VO). Figure 1 presents an example of GRID system.

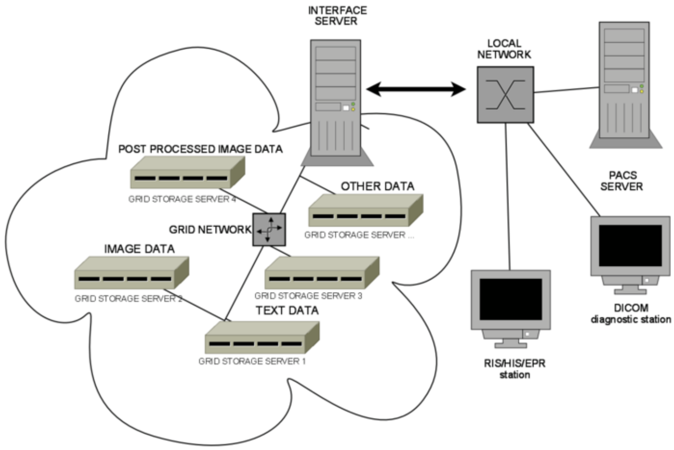

Figure 1. Scheme of GRID type solutions (example)

Kardionet, due to the legal regulations, must solve a problem of seamless and secure access to the distributed data owned by the different legal entities. In addition, the large multidimensional data has to be processed in the shortest possible time which requires on demand access to the high performance computing systems. The best solution which provides such functionality is GRID technology designed to provide access to the resource across administrative domains. GRID provides strong authorization and authentication methods based on the certificates and/or login-password pairs, allows to organize users in Virtual Organizations with flexible and extensible control of access, and provides mechanism to access and process distributed data. Recent advances in GRID allows to perform these tasks in an easy and comfortable way both from the administrators and users point of view and uses all the advantages of the distributed system and high level software infrastructure to integrate, manage and archive sources of distant locations. At the same time it optimizes the efficient realization of the aim of the whole system.

The multimodal Kardionet system devoted to cardiology purposes includes data bases for multimodal data and metadata, with information on the patient and his/her medical examination results. One of the aims of the project was creation of the module for image processing for the purposes of diagnosis and therapy planning. The second created module was a format of the multimodal electronic patient record (EPR) that should be possibly general in character with a special part useful mainly dedicated to cardiology. The next step was the construction of the three-level cardiological data processing system that operates in the shortest possible time and provides advanced visualization. This data processing system ensures a high level of data security. Additional features of Kardionet are: possibility of teleconsultation, decision making support system and a system of matching medical cases on the basis of similarity of multimodal data.

3. Methods

The main purpose of the Kardionet telemedical system was to build and to develop tools for the integration and the interpretation of 3D or 4D image-type data. Here, data from image diagnostics (CT, Magnetic Resonance Imaging, ultrasonography, angiography) is used. Available methods of acquisition without use of additional software do not allow for a direct 3D image creation. Also, 3D reconstruction performed on the basis of angiographical imaging data has to take into account its quality. That quality which can be improved with the special software used in the system has a considerable impact on the reliability of anatomical 3D images.

The system is still being developed. Current work is focused on building the tools for the visual assessment of spatial correlations and physiological processes that change in time. We use co-registration methods showing (in space and time) compatibility of information coming from different sources and different points of time. Then, data are merged to enable identification of the selected elements.

Next element of the described telecardiological system is the format of the EPR which had been built with open source/free software. The most popular solution for internet applications – used also in our case – is the three-layer client-server architecture. Such a choice ensures that the EPR can be used by various medical centres cooperating with each other and implementing new www applications. EPR was written in Java JEE and is based on multilayer component architecture that is set on application server operated by Java Application Server. Its principal advantage is the possibility to create dynamic websites cooperating with numerous types of data bases [2]. EPR structure includes procedures that use both structured data entry and flexible free text. Structured data could be entered with the help of partially formalized hierarchical system. A multimodal patient record includes demographic characteristics of patients, medical interview, basic examination results and various methods of treatment. All additional examination can be also added to the EPR. Data that can be entered facilitate risk assessment for the acute coronary syndrome (ACS) and will be used for future teleconsultation system. Usage of the solutions described above required implementations of standards for text data transmission (HL7) and for image data transmission (DICOM) [3]. That had an impact on a choice of the data base, PostgreSQL, which takes into account structure, size and possibility of quick and reliable work with this type of data, as well as XML for unification of all elements of the system.

Management of ACS should be guided by an estimate of patient risk. Risk stratification in ACS aims at prompt identification of the higher-risk patients (who will benefit from more invasive investigation and treatment) and of the lower-risk patients. Risk stratification is done on the basis of patient history, physical examination, electrocardiogram and biochemical markers. There are also some new markers such us B-type natriuretic peptide (BNP) with proven prognostic power.

Emerging approach to ACS is to use comprehensive method for risk assessment. Risk scores (e.g., SIMPLE, TIMI STEMI, GRACE, ZWOLLE, their detailed description can be found in [4–7]) were developed to facilitate an early risk stratification. They incorporate important demographic, clinical, ECG and blood marker parameters shown to be independent predictors of prognosis. Figure 2 presents risk assessment for 30-day-survival of a patient using above-described scores.

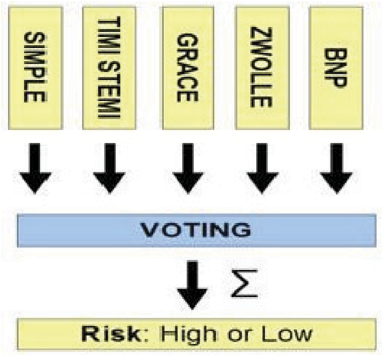

Figure 2. ACS risk assessment scheme proposed in EPR

Risk stratification with a scoring system on admission offers the best way to identify high risk patients. Clinical predictors can be included in computer programs, such as expert systems, and used for risk stratification. This can support decision making for ACS patients.

Next module, for similar cases matching, searches for the medical cases in the database matching a given case on the basis of similarity in multimodal data. Description of data contents (value, texture, geometry, etc.) should be verified for images being compared. In this module it will be possible to provide teleconsultations within local systems as well as international systems, like EuroRad. It will be also possible to support diagnoses by indicating cases with similar description on the basis of (among others) MPEG-7 standard.

4. Security of the System and Data Exchange/Transmission

Many standard security functions such as authentication, access control, integrity, privacy and non-repudiation are required in telecardiological GRID systems. Here the focus will be mainly on issues related to authentication and access control (authorization). In GRID systems authentication and authorization functions are executed in user context as well in process context. The processes perform computation on behalf of user and resource context used by those processes. We can distinguish different mechanisms of mutual authentication (see e.g., [8]).

It is important that authentication mechanisms described above are realized on a global level and should cooperate with local access control systems embedded in every node taking part in the GRID system. Authentication can be done in many ways: using clear text passwords (not recommended), Kerberos protocol or other available authentication solutions. Good example of elimination of clear text passwords is to use SSL protocol based on Public Key Infrastructure certificates in combination with X.509v3 standard. One of the positive aspects of using SSL protocol is that SSL has been proven in a public domain library called SSLeay, which is used in many authentication systems in the world. And thus SSL is used as a method for authentication and secure communication in many distributed services such as HTTP servers, web browsers and directory services.

5. Conclusions

Generally, solutions and tools developed within the Kardionet project are equally competitive as other technologically advanced European projects, like CAROLIN in Italy or AIDMAN in the UK and Greece.

As Kardionet uses modern technology and methods we expect it could have a considerable impact on telemedicine development in Poland and worldwide. The telecardiological system built in the presented project can provide a number of important gains for the national health care system if it is implemented nationwide. At present it is used only in Mazovia District with the main reference centre in Warsaw.

Processing and management of multimodal 3D and 4D data will be more and more important in future, as they contribute to a very effective decision support system for better diagnosis and treatment of cardiovascular system diseases.

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